Emergency Location

Delivering
Portability & Precision

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INTRODUCTION

1. The advent of Search & Rescue Satellite-Aided Tracking (SARSAT) in the mid-1980's saw the launch of a new and radically different international distress signal centred around 406 MHz. The 406 MHz waveform was quite different to the traditional 121.5 MHz distress frequency not least because it was encoded with digital data which uniquely identified the beacon and its country of registration. In addition, the 406 data message included provision for encoding position co-ordinates using 'location' protocols. For installed marine or aircraft emergency transmitters, the position co-ordinates were typically derived from on-board navigation equipment such as GPS.

2. The challenge, however, was to integrate 406 MHz 'location' functionality in a man-portable Personal Locator Beacon (PLB) while still keeping weight and size to a practicable level that facilitated carriage in a standard aircrew life-vest. In addition, the 406 data message created the opportunity to enhance the capability of SAR homing systems by decoding and displaying message information including GPS-derived latitude and longitude.

AIM

3. The aim of this paper is to outline the developments in SAR Satellite Aided Tracking and to discuss recent developments in SAR emergency beacons and associated airborne detection and tracking systems.

A GLOBAL APPROACH TO SEARCH AND RESCUE

4. COSPAS-SARSAT is an internationally funded global Search and Rescue Satellite Aided Tracking system comprising orbiting satellites and ground infrastructure that detects, identifies and locates activated emergency transmitters or beacons and processes this information to co-ordinate a timely rescue. The system currently uses two separate satellite constellations:

- Low Earth Orbiting (LEO) Satellites.
- Geostationary Earth Orbiting (GEO) Satellites.

5. The LEO satellites maintain a height of about 600 miles above the Earth's surface with their orbits coinciding at the poles. Under these conditions, a LEO satellite takes

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approximately 100 minutes to complete one orbit, while to an observer on the ground, the satellite takes about 15 minutes to travel from horizon to horizon. In low Earth orbit, a satellite is limited in terms of its visible horizon to an area of the Earth's surface measuring about 4,000 miles in diameter. Consequently, with four LEO satellites in operation it can take up to one hour for an activated beacon to be detected – termed 'satellite waiting time'. Importantly, the LEO satellites' relative velocity with respect to the Earth's surface allows the position of an emergency transmitter to be determined by measuring the variation in Doppler frequency as the satellite overlies the beacon. The accuracy of this position fix varies from around 12 miles on 121.5 and 243 MHz to around 3 miles on 406 MHz. Moreover, the time taken to determine position unambiguously (known as 'location' waiting time) on 121.5/243 MHz is approximately twice that needed to locate a beacon on 406 MHz.

6. LEO waiting time clearly represented a significant delay both in terms of detection and location, with consequent implications for human survival. The LEO satellites were therefore later augmented with a constellation of Geostationary Earth Orbiting (GEO) satellites located some 22,300 miles from the Earth. Operating on 406 MHz only, the GEO satellites are positioned directly above the Equator and orbit in synchronism with the Earth's rotation with the result that the satellites appear in fixed locations above the Earth's surface. Currently, four GEO satellites continuously monitor the whole Earth's surface within +/- 80° latitude. The benefit of the GEO satellites is that their much wider field of view provides near instantaneous detection and identification on 406 MHz within +/- 80° latitude; however, they have limited coverage in the Polar regions and the absence of relative velocity in relation to the Earth's surface precludes Doppler location.

7. Towards 406 MHz Only. In the mid-1980's, there were few 406 MHz emergency transmitters and virtually no portable beacons capable of operating on this frequency. An effective transition to satellite-aided SAR could not therefore be achieved overnight. From the outset, COSPAS-SARSAT therefore provided a basic satellite service on 121.5 MHz and, to a lesser extent, on 243 MHz. However, satellite design constraints and the absence of data on these frequencies meant that 121.5 and 243 MHz beacons would never receive the level of service available to 406 MHz users. COSPAS-SARSAT continues to offer a service on 121.5 / 243 MHz but this is available only via the LEO satellites, and therefore does not provide the immediate detection and identification available to 406 MHz users via the GEO satellites. More importantly, due to the high level of false alerts and increasing levels of signal traffic generally, COSPAS-SARSAT have decided to terminate the 121.5/243 MHz service by February 2009. A transition to 406 MHz emergency transmitters by this time is therefore essential if operators are to continue to benefit from a global SAR service.

WHY USE GPS?

8. The time taken for LEO satellites to achieve an unambiguous Doppler position fix on an activated beacon can, in the worst case, take up to 2 hours – an elapse time that is plainly critical to any survivor in a hostile environment. Not surprisingly, therefore, satellite message protocols made early provision for the insertion of positional data into the 406 MHz message to permit location data to be relayed directly via the GEO satellites with minimal delay. This meant that the locating process could not only be completed much more quickly but it also enabled significantly improved, GPS-derived accuracy approaching 330 feet (100 metres), effectively limited by 406 MHz message capacity. Initially, only installed maritime and, subsequently, aviation emergency transmitters were able to make use of this 'location' protocol option. The challenge, therefore, was to incorporate a GPS capability within a portable Personal Locator Beacon, thereby offering an individual the same probability of early and accurate location as that afforded to an aircraft or ship in distress.

TECHTEST SERIES 500-27 LOCATION PROTOCOL BEACON

9. Techtest Ltd (part of the H R Smith Group of Companies) pioneered the development of the first stand-alone GPS Location protocol emergency beacon to be fully COSPAS-SARSAT certified and TSO/JTSO approved. The Series 500-27 beacon provides full 406 MHz 'location' capability together with transmissions on 121.5 and 243 MHz, and two-way voice communication on these frequencies.

10. From the outset, emphasis was placed on building in supportability with a modular design and field-replaceable components. The beacon is a 'Class 2' equipment (operating range: -20 to +55 °C) and it is water-proofed to a depth of 33 feet. Options for manual or automatic activation are available, while the beacon's compact size makes it ideally suitable for carriage in an aircrew life vest or in an ejection seat Personal Survival Pack (PSP). The beacon sustains continuous operation on 406 MHz at –20° C for 24 hours, while continuing to operate for a further 24 hours on 121.5 and 243 MHz in accordance with EUROCAE ED-62. This performance is achieved with a single, fully sealed battery pack which provides a sliding fit into a recess in beacon's lower case.

11. **Antenna Configurations.** A range of antenna configurations is available, including a life-vest mounted flexible whip antenna for over water operations. The unique design of the beacon's integral multi-band antenna, which is tuned specifically for the 3 frequencies of operation, maximizes RF performance and thereby enhances the prospect of early satellite detection and recovery by rescue forces. These capabilities were admirably demonstrated during recent trials in the USA in which the Series 500-27 beacon was the only unit under evaluation to successfully penetrate a dense tree canopy.

12. **Portability & Capability.** The 500-27 beacon features a single thermoplastic moulded casing which offers exceptionally low weight, ease of carriage and high durability. Function-for-function the beacon is one of the smallest (5.9 x 3.4 x 1.5 inches) and lightest (23 ounces) in its class; moreover, other production beacons that may be comparable in weight and size with the 500-27 typically do not feature the same level of functionality. For example, the AN/URT 140, though similar in weight and size to the Techtest 500-27, has neither GPS nor speech capabilities. On the other hand, while the AN/PRC 149 provides GPS and speech, it is significantly larger and heavier than the Series 500-27 beacon. Table 1 below summarizes functional and physical characteristics of the foregoing units against the baseline AN/URT-33 beacon:

CHARACTERISTIC	AN/URT-33	AN/URT-140	AN/PRC-149	Techtest 500-27
406 MHz	No	Yes	Yes	Yes
121.5 MHz	No	Yes	Yes	yes
243 MHz	Yes	Yes	Yes	Yes
Embedded GPS	No	No	Yes	Yes
Speech	No	No	Yes	Yes
Weight (ozs)	17	24	30	23
Dimensions (ins)	2.5 x 4.5 x 1.25	2.6 x 4.6 x 1.25	3.5 x 7.5 x 2	3.4 x 5.9 x 1.5
Volume (cu ins)	14	15	52.5	30

Table 1

13. **Reprogramming 406 MHz Data.** Because each 406 beacon contains a unique identification code, the need to re-program the unit can arise from time to time, especially

when programmed with information relating to its parent platform. Consequently, a reprogramming capability is incorporated in all Techtest 406 MHz beacons which allows message data to be changed by the operator using a standard PC (or laptop) equipped with the 'MS Windows' operating system in conjunction with a special adaptor module and lead. This feature significantly enhances beacon supportability and, in combination with comprehensive Built in Test (BIT), means that return of beacons to the manufacturer would be necessary only in the unlikely event of an internal transmitter fault.

DELIVERING OPERATIONAL CAPABILITY

14. The Techtest 500-27 location protocol beacon provides an individual, whatever his geographic location, with a portable and global means of immediately alerting the COSPAS-SARSAT rescue authorities via one of four Geo-stationary Earth Orbiting (GEO) satellites which, together, provide near whole earth cover. The beacon's ability to determine its position using GPS and transmit this latitude and longitude as part of the 406 message virtually eliminates location waiting time and provides position accuracy to approximately 330 feet (100 metres). In the event that GPS satellites cannot be acquired, Low Earth Orbiting satellites will subsequently obtain a geographic Doppler position fix of the survivor's location to approximately 3 miles accuracy when they next over-fly the activated beacon. Thus, the COSPAS-SARSAT system and the complimentary development of 406MHz 'location protocol' emergency beacons effectively eliminates the 'search' element from SAR operations thereby bringing essential, life-saving improvements in the speed and conduct of rescue operations, globally.

15. **Benefits of Speech Capability.** The beacon's two-way speech capability on 121.5/243 MHz allows a survivor verbally to alert rescue forces of his whereabouts and status/condition once the SAR aircraft is within visual (or audible) range. This facility not only provides important reassurance to the survivor but also potentially allows him to guide the SAR aircraft to his precise location when in difficult or obscured terrain. This important added capability reduces mission risk and rescue time, with consequent improvement in survivability prospects.

16. **Auto-Activation.** A survivor of an air accident or incident may not be in a position to activate an emergency beacon in a timely manner due to injury or even oversight. This scenario is particularly relevant to aircrew flying high performance aircraft equipped with ejection seats and led Martin Baker Ltd to develop an innovative mechanism for activating a beacon which is packed in the seat's Personal Survival Pack (PSP). Here, a simple mechanical linkage operates the beacon's on/off switch to activate the beacon as part of the seat's automatic deployment sequence, thus ensuring that the beacon is transmitting during the parachute descent. This simple but effective mechanism ensures that the beacon is activated at the earliest possible opportunity regardless of the physical condition of the ejectee. For the future, it is planned to develop this concept further with an electronic auto-activation module.

17. **Multiple Beacons.** In the event of more than one beacon being activated in close proximity, a collective power management feature automatically suppresses 121.5 and 243 MHz transmissions from all but the initial (master) beacon. Importantly, this innovative feature reduces the possibility of multiple distress signals disrupting the operation of SAR homing systems - a problem that is known to occur when using traditional homing methods in a multi-beacon environment. The feature also ensures that speech transmissions are not corrupted, and multiple survivors automatically benefit from extended co-operative beacon operating time because of the suppressed transmissions. Transmissions on 406 MHz

however, continue uninterrupted in order that the satellites may have full visibility of the rescue situation on this frequency.

PROVEN PERFORMANCE

18. The Techtest Series 500-27 GPS beacon was subject to a recent test programme conducted by the US Coast Guard on behalf of the COSPAS-SARSAT Joint Committee the results of which were reported at Reference A. The tests were aimed primarily at evaluating overall system performance, accuracy, availability and timeliness using a range of 406 MHz location-protocol beacons. The trials revealed that the Techtest 500-27 beacon gave 100% message availability and delivered a 90% success rate in transmitting positional data to within 0.6 miles (1km) accuracy. A 100% success rate was achieved to a location accuracy of 3 miles (5 Km). In addition, the beacon was consistently in the top grouping for a range of land and sea trials which included varying degrees of GPS visibility. Of particular note, the Techtest beacon was the ***only*** product to successfully penetrate a high-density tree canopy – an achievement which is considered to reflect the beacon's synergistic qualities of inherent electronic design and highly optimized antenna performance.

19. A similar non-GPS beacon was loaned to the Royal Air Force for homing trials by the School of Combat Survival & Rescue in year 2000. Their report at Reference B concluded that the Techtest beacon performed well from a homing reception standpoint in a range of trials conditions conducted on 121.5 and 243 MHz. Also, SAR aircrew were able to discriminate successfully between dual beacons transmitting simultaneously. The report further concluded that the Techtest beacon would be a worthy candidate for consideration as a replacement for the RAF's current dual-frequency beacon under the MoD Personal Emergency Locator System (PELS) programme.

20. **Maximizing Homing Range.** The range performance achieved by any beacon is dependent on many variables, most of which are governed by the physics of electromagnetic wave propagation. First, is the effect of the earth's curvature which limits line-of-sight range. Secondly, the radiation pattern of the beacon's antenna, and the relative position of the SAR aircraft will affect the received signal strength and hence detection range. In particular, radiation coverage over land, and to a lesser extent over water, is attenuated at very low angles of elevation because neither medium is a perfect electrical conductor. Detection ranges therefore reduce unavoidably in the low elevation zone. In addition, radiation in the area immediately above the beacon is also much attenuated. Notable, the consequent loss of homing signal in this zone can positively assist SAR aircrew by indicating that they are close to an overhead position. It is therefore important that range performance be considered in the context of line-of-sight constraints and beacon radiation coverage at high and low elevations. In this respect, antenna coverage and radiation efficiency are critical factors in achieving effective beacon performance – criteria upon which Techtest has always placed great emphasis. Furthermore, received signal strength at the airborne homer installation will vary according to the square root of the distance – ie a beacon transmitting at 100 milli Watts radiated power (European standard) will achieve 1.4 times the range of a 50 milli Watt beacon transmitting under similar circumstances. In trials, the Techtest Series 500-27 has achieved a homing range on 121.5 MHz (100mW) of 55 nautical miles with a SAR aircraft at 10,000 feet AGL.

CURRENT DEPLOYMENT

21. Emergency beacons in the Series-500 range (including the 500-27 GPS unit) have been successfully installed by Martin Baker Ltd in ejection seat Personal Survival Packs

(PSPs) fitted to a range of aircraft including the BAE Systems Hawk, the North American Harvard trainer, the AL-X Super Tucano, and the Northrop F5. These installations feature the previously described automatic activation mechanism initiated as part of the seat deployment sequence. Most recently, the 500-27 beacon was selected for the ejection seat of the Joint Strike Fighter (JSF) F35 demonstration phase aircraft. The Techtest 500-27 GPS beacon is currently in service or entering service with the following nations:

- Royal Norwegian AF - Life-vest & life raft mounted
- Singapore Air Force - Life-vest mounted
- Brazilian Air Force - Ejection Seat mounted - AL-X.
  - Ejection Seat mounted - F5 Upgrade.
- NFTC Programme - Ejection Seat mounted Hawk & Harvard upgrading from 500-12.
- Joint Strike Fighter - Ejection seat mounted – F35 SDD aircraft.

TOWARDS DIGITAL LOCATING

22. Compared with the use of traditional analogue homing techniques, the introduction of a digitally encoded emergency distress frequency (406 MHz) created an opportunity to achieve significant improvements in the effectiveness of SAR operations. The encoded distress signal not only enables the emergency beacon to be uniquely identified, but also to be located by encoding its position in a location protocol. Clearly, the primary aim of this information is to alert and assist the rescue authorities via the COSPAS-SARSAT satellite system. However, by incorporating a digital 406 MHz message decoder in an airborne homing system, the SAR aircraft is able to identify the source of the distress transmission for itself and also determine the transmitting beacon's position. In turn, this capability gives the SAR aircraft autonomy of operation and reduces the inevitable data latency associated with the distribution of information across the COSPAS-SARSAT communications network.

23. The Techtest Series 406-16 Homer-Decoder, which is currently in the final stages of development, displays the beacon's ID and position co-ordinates in alpha-numeric form on an integral, NVIS compatible indicator. Additional beacons may be displayed using a simple scroll mechanism, thereby eliminating the problems associated with multiple beacon discrimination on traditional distress frequencies. Decoded latitude and longitude can also be compared with on-board navigation data to calculate automatically each beacon's relative position with respect to the SAR aircraft. In turn, the pilot receives a range and heading to steer directly towards the selected beacon. Importantly, once a beacon's position has been decoded, the SAR aircraft is able to fly on an intercept heading without maintaining continuous line-of-sight visibility, thereby providing added protection in hostile environments. The 406 MHz data decode function therefore effectively provides a covert, single-pass rescue capability while overcoming many of the limitations associated with analogue homing.

24. Notwithstanding the benefits of decoding the 406 data signal, it is nevertheless considered essential to retain analogue homing functionality and to provide an appropriately timed transition from data decode to homing mode. This is particularly important for beacons operating in a non-location or short message (reduced accuracy) mode. The series 406-16 Homer-Decoder therefore retains a comprehensive homing capability for AM, FM, UHF and 406 distress frequencies.

25. **Flexibility of Installation & Deployment**. The series 406-16 Homer-Decoder features appropriate external interfaces to facilitate integration with electronic map systems and multi-function displays. In addition, its compact (5.8 x 2.6 x 6.1 inches), self-contained design, which requires connection to just one pair of homing antennas, offers a rapid role-fit capability to potentially enable any aircraft to contribute effectively in a SAR emergency. In short, the Homer-Decoder closes the digital 'data loop' by ensuring the real-time availability of essential 406 message information to Search & Rescue crews during a rescue operation, while concurrently providing interoperability with non-406 MHz legacy equipment.

CONCLUSION

26. Satellite-aided search and rescue transformed the effectiveness of SAR operations worldwide. The combined use of a comprehensive, integrated network of low orbiting and geostationary satellites now offers benefits of rapid detection and identification, together with Doppler location, thus allowing SAR forces to mount rescue missions with unparalleled efficiency and speed. Furthermore, complementary developments in 406 MHz portable beacon technology have ensured that the advantages of this global SAR system can be fully exploited to maximize human safety at the individual level.

27. Moreover, the latest Techtest Series 500-27 emergency beacon with its integral GPS receiver has achieved further significant capability improvements by providing near-instantaneous location and enhanced accuracy to within 330 feet. Additionally, the integration of 121.5/243 MHz traditional distress transmissions and two-way speech offers sufficient capability breadth and performance to cater for virtually any rescue scenario. Meanwhile, concurrent development of homing technology to incorporate 406 MHz data decoding functionality in the Techtest Series 406-16 Homer-Decoder further exploits the benefits of this digitally encoded signal and allows SAR aircraft independently to locate multiple activated beacons and fly a direct and precise course without maintaining line-of-sight contact.

28. These products reflect the H R Smith Group's continuing commitment to the development of new and innovative Search and Rescue solutions that deliver ***portability*** **and** ***precision*** in the field of ***emergency location*** and rescue.

Barry Thrower
H R Smith Group of Companies
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Reference A: Test Report JC-17/5/16 dated 11th June 2003.
Reference B: RAF Report SCS/3309/2/Trls dated 22nd January 2001.

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Resume

Barry Thrower joined the Royal Air Force in 1962 and underwent a 3 year apprenticeship in radio engineering. He was later commissioned in the Engineer Branch and served in a range aero-systems management and headquarters appointments specializing in avionics on fast-jets and rotorcraft. He retired from the RAF as a wing commander in 1998 and joined the H R Smith Group of Companies as UK Business Development Manager. In this role he has written papers and presented widely on the Companies work in the Search and Rescue field, including several SAFE Europe conferences and other military and civil forums.